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PROWLER INTEGRATION INTO USAF STRATEGIC ATTACK AND AIR INTERDICTION MISSIONS

A MONOGRAPH
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ABSTRACT

PROWLER INTEGRATION INTO USAF STRATEGIC ATTACK AND AIR INTERDICTION MISSIONS by Major Michael F. Hake, USAF, 41 pages.

The importance of protecting limited aircraft assets cannot be overstated. The loss of a modern aircraft entails the probable loss of highly trained and experienced crews that took years to develop. Furthermore, if a target is missed because of defensive reactions to radar-guided weapons, the sortie is lost and the target will have to be attacked again, draining valuable resources from the war effort and risking the attack package all over again. Therefore, the jamming of early warning, ground-control intercept, and acquisition radars maximizes the success of strike packages by creating significant confusion and friction inside the command and control system of an adversary by denying critical intelligence on aircraft routes, altitudes, and timing. This friction slows an adversary's ability to respond to aerial attacks and therefore contributes directly to the preservation of experienced combat crews and aircraft.

Joint Publication 3-01.4 defines Electronic Warfare (EW) as "any military action involving the use of electromagnetic energy and directed energy to control the electromagnetic spectrum or to attack the enemy." EW is further divided into three subcategories: Electronic Attack (EA), Electronic Protect (EP), and Electronic Warfare Support (ES). All three of these subdivisions are critical to the creation of synergistic effects in the modern electromagnetic battlefield. The Air Force's decision to retire the EF-111A and join the Navy in the creation of four EA-6B Joint Expeditionary Squadrons highlights a significant shift in the EA philosophy of the Department of Defense and forms the basis for this monograph.

Though the stealthy B-2 and F-117 garner a great deal of attention, these aircraft represent only a small percentage of the United States aerial arsenal. Moreover, the proliferation of radar-directed surface-to-air missile and anti-aircraft artillery threats continue to require the US to maintain a robust EA capability. Thus, the United States Air Force will continue to need an EA platform to provide tactical jamming support to non-stealthy aircraft in a medium-to-high threat environment during joint or combined operations. This monograph assesses whether or not the Navy's EA-6B possesses sufficient combat capabilities to provide successful EA support to Air Force strategic attack and air interdiction operations. Research indicated that by continuing current Prowler modernization plans, upgrading mobility capabilities, enhancing integration of Air Force officers into the Replacement Air Group and the Electronic Attack Weapons School, and by raising the priority and funding given to returning EA-6B squadrons, the EA-6B Prowler is capable of successfully countering the modern IADS in support of USAF contingency operations.

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Introduction

> "From the very beginning the British had an extraordinary advantage which we could never overcome throughout the entire war: radar and fighter control. For us and our command this was a surprise, and a very bitter one."[1]
>
> Adolf Galland
> WWII Luftwaffe Ace

History has repeatedly demonstrated man's ability to develop countermeasures to new weapon systems. The birth of radar reflected this trend in that radar was developed to counter a growing air threat. The accurate detection of hostile formations in bad weather or at night became a practical reality and formed the cornerstone of modern air defense systems.[2] Changes in radar technology have resulted in the development of new countermeasures, which in turn led to the necessity of developing more advanced radar technologies. Hence, the cyclic history of radar development and radar countermeasures demonstrates the driving nature of technological improvements upon the development of electronic warfare doctrine and equipment.

The British were the first to develop an integrated air defense system (IADS) during the 1930's by building radar sites along their eastern coastline in order to provide early warning of air attacks originating from continental Europe.[3] During World War II, the information provided by these sites was correlated by operations centers to develop an integrated air picture enabling Fighter Command's limited assets to gain the greatest effects against the German Luftwaffe during the Battle of Britain. Moreover, the history of World War II documents the progressive development of electronic combat doctrine and new equipment, such as chaff and radar jammers by the Allies in order to suppress German radar sites during aerial attacks against Germany. The purpose of the suppression of German radar systems was to mitigate the effectiveness of radar directed anti-aircraft artillery (AAA). Thus World War II gave birth to modern Electronic Warfare. The requirement to protect aircraft against radar directed weapon systems has grown exponentially with the development and employment of vast numbers of modern radar directed surface-to-air

missile (SAM) systems and advancements in radar-guided anti-aircraft artillery. Most recently, Desert Storm witnessed the invaluable contribution of dedicated electronic attack aircraft in the skies over Iraq.

The Desert Storm aerial campaign was designed to gain air superiority as quickly as possible to permit unimpeded Coalition air and ground operations throughout the theater. Iraq possessed the most modern and sophisticated integrated air defense system the US has faced to date. Coalition forces faced over 600 SAM units, including Soviet SA-2, SA-3, SA-6, and SA-8; the Chinese HN-5; the French/German Roland 2; and 10,000 anti-aircraft artillery pieces including radar controlled 57-, 85-, 100-, 130-mm guns and ZSU-23-4 systems.[4] This integrated air defense system was generally employed in accordance with Soviet doctrine. The Coalition countered by employing NATO doctrine to disrupt and destroy the Iraqi IADS, which had been developed based on experience against Soviet systems gained from operations over North Vietnam, recent Middle East conflicts, and the US raid against Libya in 1986.

The ultimate success of the offensive electronic combat campaign resulted only 10 of the 38 Coalition aircraft lost during Desert Storm were damaged or destroyed by radar-guided SAMs.[5] General Horner stressed in early February 1991 that American support for the war depended in large measure on the ability to operate "with less than anticipated" losses of human lives among Coalition airmen, soldiers, sailors, and Marines.[6] The presence of EF-111A and EA-6B tactical radar jammers contributed significantly to the achievement of that objective. By the time Desert Storm ended, the Coalition's loss rate was about one fixed-wing aircraft per 1800 combat sorties.[7] This loss rate was 4.7 times lower than that experienced by the US over North Vietnam from January to December 1967 and some 14 times lower than that experienced during Linebacker II operations at the end of US involvement in December 1972.[8] The low loss rates stemmed from US electronic superiority and the decision to bomb from medium altitude after the first week. The effectiveness of tactical radar jamming against radar-guided SAMs and AAA allowed effective

medium altitude operations to be employed, reducing the risk of Coalition aircraft to infrared SAM systems and small caliber AAA encountered at lower altitudes.

The importance of protecting limited aircraft assets can not be overstated. The loss of a modern aircraft entails the probable loss of a highly trained and experienced crew that took years to develop. Furthermore, if a target is missed because of enemy reactions to radar-guided weapons, the sortie is lost and the target will have to be attacked again, draining valuable resources from the war effort and risking attack aircraft all over again. Therefore, the jamming of Iraqi early warning, ground-control intercept, and acquisition radars maximized the success of strike packages by creating significant confusion and friction inside the Iraqi command and control system by denying them critical intelligence on Coalition aircraft routes, altitudes, and timing. This slowed their ability to defend against Coalition attacks and therefore contributed directly to the preservation of experienced combat crews and limited assets.

Joint Publication 3-01.4 defines Electronic Warfare (EW) as "any military action involving the use of electromagnetic energy and directed energy to control the electromagnetic spectrum or to attack the enemy."[9] EW is divided into three subcategories: Electronic Attack (EA), Electronic Protect (EP), and Electronic Warfare Support (ES). All three of these subdivisions are critical to the creation of synergistic effects in the modern electromagnetic battlefield. Joint Publication 3-01.4 further defines EA as "the use of electromagnetic or directed energy to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability."[10]

The proliferation of highly sophisticated surface-to-air missile systems, early warning and ground controlled intercept radars, and abundant numbers of radar-directed anti-aircraft artillery weapon systems require a robust EA capability. Even though the stealthy B-2 and F-117 garner a great deal of attention, these aircraft are a relatively small percentage of the total US fighter/bomber force. Thus, the United States will continue to require an electronic attack tactical

radar jamming platform that can provide support to non-stealthy aircraft in a medium-to-high threat environment in a joint or combined atmosphere.

In December 1994, the USAF decided to retire the EF-111A, to rely upon the Navy's EA-6B for tactical jamming support during contingency operations, and to integrate the tactical jamming mission as a joint effort.[11] The integration issue is of the highest importance in view of the USAF's decision to retire the EF-111A and thus eliminate its organic tactical radar jamming capability due to fiscal constraints. In light of that decision, the USAF agreed to provide a constant pool of Electronic Warfare Officers and pilots to the Navy in order to facilitate joint operations and to allow the USN to support USAF operations. The purpose of this monograph is to answer the question: Can the US Navy's EA-6B Prowler successfully provide Electronic Attack support to US Air Force strategic attack (SA) and air interdiction (AI) missions in a medium-to-high threat integrated air defense environment? This monograph will explore this joint effort and attempt to determine whether or not the Prowler will be able to successfully support USAF SA and AI missions in the face of a medium-to-high threat integrated air defense system (IADS). The research materials used open sources as well as interviews and correspondence with members of the EA-6B community.

Four questions will be answered in order to determine whether or not the EA-6B will successfully function as an EA asset within USAF SA and AI attack missions. First, are the crew members of the EA-6B community being taught the skills necessary to successfully integrate their capabilities with USAF attack aircraft by the Replacement Air Group? Secondly, is the Prowler-USAF community being integrated by means of realistic training scenarios and exercises within the United States as well as overseas and do these exercises actually reflect real-world contingency capabilities? Thirdly, does the EA-6B possess the capability to support the omnidirectional threat picture found in a medium-to-high threat IADS environment? Finally, have successful work arounds been created for EA-6B airframe limitations versus the USAF aircraft they would support?

Historical Development of Tactical Radar Jamming

The origins of electronic combat and radar theory can be traced to Heinrich Hertz of Germany who in 1888 discovered that electromagnetic energy can be propagated through the atmosphere at the speed of light.[12] The years following Hertz's discovery witnessed the spectacular development and growth of wireless radio technology as the first practical application of controlled electronic wave propagation through space. In turn, research into the properties and applications of electromagnetic waves opened the door to the realm of radar development and in turn the modern concept of electronic attack. Changes in radar technology continue to drive the development of new electronic countermeasures and result in the revision of existing electronic warfare doctrine of the time; an endless cycle of electronic countermeasure versus electronic counter-countermeasure. The art of electronic warfare is constantly trying to stay even with new technological breakthroughs and the ever increasing sophistication of radar-guided threats.

At the turn of the twentieth century, scientists pursued research into the use of electromagnetic waves for the detection of objects. These devices would later be known as radar, meaning "radio detecting and ranging." One of the earliest examples of radar development can be traced to Christian Hulsmeyer, of Germany, who created the "Telemobiloscope" in 1904.[13] This device possessed a transmitter and receiver mounted side-by side that could detect ships crossing through its beam. This first attempt at a radar system relied on the interruption of a continuous wave form in order to detect the passage of a ship. While being able to detect the passage of a ship, the use of a continuous wave did not allow for range determination. Thus, while Hulsmeyer's system could detect ships or objects out to 3,000 meters, there was no way to determine whether the object was at 500, 1200, or 3,000 meters.[14]

Between World War I and World War II, the United States, Germany, and Great Britain, devoted significant effort and resources towards the development of an effective radar device. The two principal employment requirements for radar were foreseen as early warning of air and sea

threats and to provide targeting information to naval guns and anti-aircraft weapons for increased accuracy and lethality.

In the United States, the US Naval Research Laboratory (NRL) began experiments with radio detection systems as early as 1922, using a continuous wave transmitter similar to that created by Hulsmeyer.[15] By 1934, the NRL had refined this interference concept and technology to the point of being able to detect an aircraft at 50 miles.[16] Once again, however, the interference-based radar system notified an operator when an object was present, but was still unable to provide range or altitude. By 1936 NRL research efforts were achieving many breakthroughs in the development of ground and air based radar systems.

In April, the NRL built its first pulsed radar, which was able to detect an aircraft at 10 miles and by June, the range had been increased to 38 miles.[17] Additionally, in April, an experimental radar was installed on the destroyer USS Leary with a range of 20 miles.[18] By December 1939 the XAF Naval radar proved successful at detecting aircraft out to 100 miles and ships at 15 miles.[19] The SCR-268 coastal and anti-aircraft system became the first radar to go into production for the US Army in 1941.[20] The use of electronic pulses allowed for the determination of range and altitude, overcoming the deficiencies of continuous wave radar systems. Thus by 1941, the United States possessed an effective radar system capable of detecting surface and air threats and of providing targeting data.

In Germany, work on the development of radar gained impetus under the direction of Dr Rudolph Kuehnold in 1933.[21] By October 1934, the Germans had developed continuous wave radar, which was able to detect ships at 7 miles. By the spring of 1936, the Germans had also developed a pulsed radar, which became known as the Freya.[22] At the commencement of World War II, the Germans possessed about 100 Freyas and employed them as the backbone of their early warning system.[23] In addition to the Freya, a new radar known as the Wuerzburg entered service in the summer of 1940 and would later be used to direct AAA, searchlights, and night fighters, as well as a height finder for the Freya.[24]

By June of 1935, Great Britain was developing pulsed radar that allowed for the detection of aircraft at 17 miles.[25] In March 1936, Britain's technological innovation resulted in the development of a radar system capable of detecting aircraft up to 75 miles.[26] The British grasped the significance of radar to defense from aerial attack and correspondingly built an integrated coastal radar network. This radar network became known as the Home Chain and was tied into Fighter Command prior to World War II.[27]

Radar was an entirely new concept in military technology at the commencement of World War II. While the stronger side generally wins in combat, history is replete with examples of the inferior force gaining a crucial advantage and defeating the stronger opponent. Radar provides the ability to detect and target an enemy aerial force enabling a defender to mass at the crucial time and place. The Battle of Britain clearly demonstrated the tactical advantage radar gave to the numerically inferior Fighter Command in combating the German Luftwaffe. The Battle of Britain is also significant in that it gave birth to the concept of electronic attack and the development of radar jammers, chaff, and deception.

The Battle of Britain began in July of 1940 with the German Luftwaffe emphasizing offensive counterair missions.[28] As part of their plan to gain air superiority, the German's primary targets were the Royal Air Force's fighters, air bases and defenses, and coastal radar sites. One of the initial and unique attempts by the Germans to degrade Britain's integrated air defense system was the employment of a radar jammer, named "Breslau," on Mount Couple in an attempt to jam Britain's coastal radars around Calais.[29] The lack of sufficient numbers of Breslau jammers and anti-jamming measures possessed by the British radar systems combined to nullify the German effort.[30] While engaged against the Germans in the summer of 1940, the British recognized the need to collect electronic intelligence on German radar systems to be able to successfully counter Axis technology prior to launching their own strategic bombardment campaign. A limited number of specially modified British Hallicrafter S-27 aircraft were built to perform this key collection

mission.[31] These aircraft patrolled German occupied territories with highly sensitive receivers in order to collect technical data for exploitation.

Great Britain exploited intelligence on German radar systems and developed the first electronic attack system designed to spoof enemy radars into indicating multiple false targets. This electronic countermeasure, code named "Moonshine," and was initially carried aboard a Hallicrafter S-27 on August 6, 1942.[32] Since the British would not be able to directly witness the affects of Moonshine against German radars, the British had to rely on German responses as an indicator of their success. British radar systems observed the success of Moonshine when German fighters were repeatedly launched against the ghost armada during dry runs conducted at night.[33] Since the Germans possessed visual observation posts to give warning of impending Allied attacks, Moonshine was only effective at night or under adverse weather conditions when Allied aircraft could not be visually detected.[34]

In December of 1942, the British introduced the Mandrel and Tinsel jammers to counter the Freya and Wasserman radars.[35] In January 1943, however, one month after employing the jammers, a British monitoring station picked up a Freya radar operating outside its previously known technical parameters requiring the British to update their jammers.[36] Until the end of the war, the Germans and the British would continue to increase their frequency diversity in an attempt to counter their adversary's countermeasures in an endless electronic countermeasures (ECM)--electronic counter-countermeasures (ECCM) cycle.

Operation Overlord is well known in terms of the land campaign, however the significant contributions of the electronic campaign are not as well known. By the evening of June 5, 1944, 76 of the 92 German coastal radar sites along the French and Belgium coasts had been attacked.[37] In conjunction with the Allied invasion, two electronic attack operations, code named TAXABLE and GLIMMER, were launched in order to deceive the Germans as to the direction and orientation of the Allied invasion.[38] GLIMMER aimed for Le Havre while TAXABLE focused on the area around Dunkirk, Calais, and Boulogne.[39] Allied bombers established a small rectangular racetrack

at low altitude and dropped chaff on the inbound leg to simulate the approach of an Allied convoy at approximately seven knots. These actions were coordinated with a small fleet of patrol craft that proceeded to within ten miles of the coast and anchored reflective balloons to simulate ships and played tapes simulating the sound effects of a fleet launching landing craft.[40] Only weak jamming was used to confuse German operators in order to allow the Germans to paint a radar picture indicating the advance of an Allied naval force.[41] Additionally, the RAF flew Lancasters and Flying Fortresses equipped with communications jamming equipment to prevent effective ground control of German night fighters being sent to investigate the ghost armada.[42] This represented the first integration and synchronization of electronic attack assets in support of a large-scale deception plan. Winston Churchill best expressed the success of electronic countermeasure used in the Normandy invasion when he said:

> "Our deceptive measures before and after D-Day, were planned to provoke confusion of ideas, their success was admirable and the consequences long withstood during the battle."[43]

By the beginning of 1945, the Allies dominated the electromagnetic spectrum using jammers and chaff.

The cost of the US electronic countermeasures program was estimated to have been $220,195,000, while the assets produced by the program were credited with saving 800 heavy bombers at a replacement cost $350,000,000.[44] The true success of the electronic countermeasures program, however, can not be measured in terms of dollars. The US electronic warfare program was credited with saving over 800 bomber crews whose experience and skills took tremendous resources and time to develop under wartime conditions.[45] Furthermore, Dr Fred Whipple pointed out that it is often overlooked that chaff and jammers significantly contributed to mission success.[46] These two electronic countermeasures allowed bombers to penetrate at lower altitudes resulting in greater accuracy in striking targets. This increase in accuracy significantly reduced the number of targets needing to be reattacked and correspondingly decreased the risk of losing experienced aircrews and limited aircraft. Additionally, by successfully striking targets the first time, military

planners could execute an air campaign without having to dedicate limited aircraft and aircrews to high risk reattack missions.

The principal target of Allied jamming efforts during World War II were the fire control radars of ground based anti-aircraft gun batteries such as the German Wuerzburg and Mannheim as well as the Japanese Tachi 1, 2, 3, and Mark IV Models 1, 2, and 3.[47] A World War II study, conducted in October 1943, on the effectiveness of jammers in reducing aircraft lost to AAA was conclusive—in 3 out of 4 aerial attacks electronic countermeasures resulted in significant reductions in losses.[48] Furthermore, during the bombing of Bremen by the US 8th Air Force, Allied losses decreased by 50 percent as a result of employing the radar jammer "Carpet."[49]

After the end of hostilities in Europe and the Pacific, the United States demobilized and mothballed most of its electronic combat infrastructure.[50] Much of the equipment was sold as surplus and most of the experienced research and development staff moved onto the private sector where radar was being developed to support the emerging civil aviation sector. However, five short years after the end of World War II, the United States found itself embroiled in another conventional conflict on the Korean peninsula.

While the Korean War was not waged on the same scale as World War II, the electronic warfare tactics and techniques of World War II were found to still be applicable. By the summer of 1952, night flying B-29s were being subjected to accurate radar-controlled AAA and limited fighter interceptions.[51] World War II jamming equipment was brought out of storage, updated to new frequencies, and flown as in the previous war. The successful employment of these countermeasure systems reduced B-29 losses by about two-thirds of what might have occurred had they not been employed.[52] The Korean Conflict proved once again that aircraft penetrating enemy territory defended by radar directed weapon systems, require electronic combat support assets to survive and to successfully accomplish the mission.

After the Korean Conflict, two aspects of the early 1950s initially hindered further development of electronic countermeasures for aircraft: the advent of the jet age, with its high

speed and high altitude capabilities; and the Eisenhower Administration's defense policies which emphasized strategic nuclear capabilities over the tactical forces.[53] The high speed and improved high altitude performance of modern jet aircraft fostered the belief that aircraft could outperform threats and survive. This belief is similar to the ones held in the United States and Germany during the 1930s. During the 1930s, the development of all metal, multi-engine bombers that could out perform the fighters then in existence led both the United States and Germany to believe that their bomber force would successfully reach the target without support. This concept was proven false during World War II when bombers suffered tremendous losses in the face of well-orchestrated integrated air defense systems using radar, anti-aircraft artillery, and fighters. The loss of hundreds of German ME-110s and Stukas, as well as American B-17s proved that bombers needed electronic support to successfully accomplish their mission. The second factor hindering the development of new electronic attack equipment were budget cuts of the Tactical Air Forces in order to support Strategic Air Forces. These budget limitations hindered research and development efforts to develop smaller cooling systems and power systems that would not penalize weight-sensitive tactical aircraft.[54]

By the late 1950s however, Soviet development and fielding of the SA-1 and SA-2 to counter the West's nuclear capable bombers reawakened interest in the use of electronic countermeasures.[55] The Soviets recognized the importance of electronic superiority to successful combat operations and codified it in their doctrine of Radio-Electronic Combat (REC). REC is defined in the Sovetskaya Voyennaya Ensiklopediya (Soviet Military Encyclopedia) as:

> "the set of measures performed for reconnaissance of the electronic material and systems of the enemy and their subsequent electronic neutralization as well as the friendly measures performed from the electronic protection of friendly electronic material and systems. Radio electronic combat measures are carried out in conjunction with the destruction of electronic material, principally by weapons that home on emissions."[56]

The shoot down of a high altitude U-2 reconnaissance aircraft over the Soviet Union on May 1, 1960 by an SA-2 proved speed and height could no longer be regarded as the primary penetration aids for the strategic bomber force, and gave new impetus to US research and development efforts

in electronic warfare.[57] This incident proved once again that aircraft penetrating a radar based defense network require electronic support. Furthermore, this typifies how the development of new electronic countermeasures fosters the development of new electronic counter-countermeasures. Finally, this example demonstrates that increased reliance upon the electromagnetic spectrum makes the control and protection of this facet of military technology a critical component to the success of modern military operations.

While the US first became aware of the Soviet SA-2 in 1953, and suffered its first loss to a modern surface-to-air missile in 1960, the effectiveness of the new surface-to-air weapon systems was to be displayed in the skies over North Vietnam five years later.[58] Aircrews confronted a sophisticated air defense network comprised of integrated early warning radars, surface-to-air missile systems, and fighters. The rising loss of US aircraft to North Vietnamese radar controlled air defenses gave birth to the modern concept of Suppression of Enemy Air Defenses (SEAD).[59]

The loss of a F-4C tactical fighter on 24 July 1965 to a SA-2 Guideline surface-to-air missile over North Vietnam ushered in a new era of electronic warfare.[60] By the end of 1965 the Air Force was forced to review its tactics and strategy as aircraft losses climbed to about 160, with most of the losses being credited to SA-2 missiles.[61] The Pacific Air Forces enemy order of battle for Southeast Asia included 14.5-, 37-, 57-, 85-, and 100-mm gun batteries with an effective altitude coverage up to 45,000 feet.[62] Furthermore, by February 1966 between 22 and 24 SA-2 systems were operational in North Vietnam.[63] Unfortunately these sites were placed off limits to attack for US bombing missions for fear of killing Soviet technicians who were helping to build the sites as well as training North Vietnamese to operate the systems.[64] This political decision required the development of a standoff tactical radar jamming platform to counter the growing radar directed threats in North Vietnam for by 1968, North Vietnam possessed an estimated 5,000 to 7,000 AAA pieces and about 150 SAM sites.[65]

In an attempt to mitigate the threat posed by radar directed anti-aircraft artillery and SA-2s, the US Air Force retrofitted the B-66C Destroyer bomber as a standoff jamming platform.[66] EB-

66s were operated from Takli and Korat, Thailand from the late 1960's through Linebacker II in December 1972.[67] The EB-66s were regarded as an interim solution and scheduled for retirement following the withdrawal of forces from Southeast Asia in the mid-1970s.[68] The development of a replacement for the EB-66 began in the late 1960s. During Linebacker II the Navy's newest radar jamming platform, the EA-6B, employing the ALQ-99F Tactical Jamming System, made its first tactical appearance.[69] The USAF later considered acquiring the Navy's new EA-6B as a replacement for the EB-66, but excluded it on the basis of inadequate flight performance.[70] While the USAF dismissed the EA-6B, its ALQ-99F Tactical Jamming System was recognized as highly capable and desirable. After evaluating multiple aircraft, the high-performance F-111A bomber was chosen to house the Air Force's new ALQ-99E. The future would witness the flight of the first prototype on March 10, 1977 and after subsequent modifications the first operational EF-111A Raven was delivered to the USAF on June 19, 1981.[71] The Air Force would go on to acquire a total of 42 EF-111As by late 1985.[72]

By the end of the Vietnam War, standoff jamming aircraft, self-protection pods, and chaff corridors, dominated Linebacker II.[73] The effective integration of attackers and electronic support aircraft into packages directly contributed to significant reductions in aircrew and aircraft losses to radar-guided missiles:

> "During the course of the air war over North Vietnam there had been a steady drop in the effectiveness of the SA-2 missile, as various countermeasures took effect. When it was first used on a large scale, in 1965, the SA-2 destroyed about ten fighter-bombers for an estimated 150 Guidelines launched: an average of one kill for every fifteen missiles. By November 1968 one aircraft was shot down for every 48 missiles fired. During Linebacker II [1972] one aircraft was destroyed for roughly every 50 Guidelines fired."[74]

By the end of the Vietnam Conflict, the United States Air Force had developed a thorough understanding of the modern electronic battlefield and had refined its electronic warfare doctrine, equipment, and tactics to counter the growing radar threat environment. The lessons learned over North Vietnam were to be proven true once again in the Middle East in the fall of 1973.

The Yom Kippur War of October 1973 demonstrated once again that air operations cannot be conducted in an environment where an integrated air defense network has full use of its communications, surveillance, and fire control systems. Israel's inability to counter Egyptian and Syrian air defenses and achieve spectrum superiority resulted in unacceptable losses during the initial stages of the war.[75] Israel's high losses clearly demonstrated the lethality of the modern IADS.

As a consequence of the humiliating defeat suffered earlier during the 1967 War, Egyptian and Syrian military forces embarked on a rapid modernization of their air defense systems. With the assistance of Soviet advisors and equipment both country's developed an integrated air defense system.[76] By 1973, Egypt and Syria had developed an air defense force consisting of approximately 180 radar sites, 400 radars, 50 control centers, and 200,000 trained personnel.[77]

In contrast to her Arab neighbors, Israel's sweeping victory in 1967 continued a string of victories going back to 1936 and failed to produce the perceived need to conduct a critical analysis of internal failures or determine significant areas for improvement.[78] Israel tended to treat Arab weaknesses as cultural and almost inevitable in the Arab approach to war, rather than poor organization and leadership.[79] The Israeli Defense Force would pay a heavy price for their overconfidence as Egypt, led by President Anwar Sadat, reorganized its military structures, rearmed, and retrained with the assistance of the Soviet Union.

Though Israel was aware of the existence of the new SA-6 SAM and ZSU-23-4 radar-directed anti-aircraft artillery gun system, they were not aware of the technological changes these systems possessed to include expanded frequency ranges.[80] Therefore, Israeli electronic warfare equipment was not designed to counter these threats.[81] Furthermore, Israel did not possess the financial resources to develop and maintain a dedicated stand-off radar jamming capability such as the EB-66 or EA-6B.[82] The lack of a dedicated stand-off radar capability resulted in Israeli losses mounting so rapidly over the Golan Heights and Sinai that on 6 Oct the Israeli Air Force (IAF)

stood down to reassess its strategy and tactics in light of the integrated air umbrella possessed by the Arabs.[83]

The IAF lost 50 aircraft in the first 3 days of the war with total losses rising to 102 by the end of the war, representing nearly 37 percent of Israel's pre-war assets.[84] Two events finally turned the tide of the air war in favor of Israel: massive resupply by the US to include new self-protection pods and retuned radar warning receivers with the capability to display SA-6 indications[85]; and a successful Israeli ground counterattack which overran and destroyed SAM sites. In contrast to the 1967 war, a commission reviewed the conduct of the 1973 war and made major recommendations for change.[86]

Israeli losses re-energized the United States military into rethinking the priority needed to fight and win in the modern electronic battlefield. The Yom Kippur War could be viewed as a proxy war between US and USSR technology. In contrast to Israel, the US possessed the financial resources necessary to develop and maintain dedicated electronic combat aircraft such as the EA-6B, EF-111A, and F-4G to counter the growing electronic threat. In light of the US orientation on a war in central Europe, the possession of dedicated electronic combat aircraft was seen as key to NATO's ability to gain and maintain air superiority. Chairman of the Joint Chiefs of Staff, Admiral Thomas Moorer noted during a 1975 Senate procurement hearing:

> "...the classic doctrine that the priority of employment of air assets must be given to gaining and maintaining air superiority over the battlefield has been proven again. Today, gaining superiority includes defeating enemy SAMs in detail. Until enemy air defenses are degraded, any application of aerial firepower will be costly."[87]

The validity of this statement would be clearly demonstrated in the Beka'a Valley of Lebanon in 1982 and over Libya in 1986.

On June 6, 1982, Israel conducted a limited war, code named "Peace for Galilee," against Lebanon to secure its northern border from terrorist attacks.[88] During a two day SEAD campaign, the IAF completely destroyed the Syrian IADS consisting of SA-2s, SA-3s, SA-6s, and ZSU-23-4s, targeting approximately 19 Syrian missile batteries in two hours on the first day.[89] The exceptional

effectiveness of the SEAD operations resulted in air supremacy and the loss of only one aircraft and two helicopters during the entire "Peace for Galilee" campaign.[90] As a result of air superiority over the SAM threat, the IAF was able to devote an extraordinary percentage of its total sorties to the attack mission.[91]

Having learned their lessons in the 1973 War, the Israelis successfully synchronized both their air and ground forces to effectively suppress Syrian batteries. Unmanned aerial vehicles were used to stimulate the SAM environment and cause Syrians to turn on their target tracking radars.[92] Electronic intelligence (ELINT) collection platforms were then used to detect, identify and locate the target tracking radars (TTRs).[93] The collection of this intelligence allowed the Israelis to map out Syria's electronic order of battle.[94] Targeting data was then passed to waiting Israeli strike aircraft. Furthermore, Israeli Army forces assisted with artillery and rocket attacks and successfully inserted a commando team tasked with destroying a key air defense communications center.[95] As a consequence of this conflict, Israel has devoted tremendous effort to improving its edge over Syria in every aspect of electronic warfare, to include UAVs and enhanced electronics for their aircraft.[96]

In April 1986, President Reagan ordered the USAF and USN to conduct strikes against Libya in retaliation for Libyan sponsored terrorism against Americans in West Germany.[97] The air plan for this operation was complex due to political restrictions and Libya's possession of a sophisticated Soviet designed air defense network composed of SA-2, SA-3, SA-6, and SA-8 missile systems.[98] The attack scheme used three EF-111As from RAF Upper Heyford and carrier based EA-6Bs to jam early warning, ground-control intercept, and acquisition radars to mask the ingress, attack, and egress of the strike packages attacking targets in the Tripoli and Benghazi areas.[99] As a result of this effective screen, the employment of high speed anti-radiation missiles (HARMs), and low-level profiles, no aircraft were lost to radar controlled threats. The experience gained in packaging long-range strikes and the effective employment of electronic combat aircraft would be called upon again in 1990 when Iraq invaded Kuwait.

The Desert Storm aerial campaign was designed to gain air superiority as quickly as possible to permit unimpeded Coalition air and ground operations. The first two systems to be targeted were the telecommunications/C3 systems and the strategic IADS radar sites, SAMS, and air defense control nodes.[100] Iraq possessed the most modern and sophisticated integrated air defense system the US has ever faced to date. Coalition forces faced over 600 SAM units including Soviet SA-2, SA-3, SA-6, and SA-8; the Chinese HN-5; the French/German Roland 2; and 10,000 anti-aircraft artillery pieces including radar controlled 57-, 85-, 100-, 130-mm guns and ZSU-23-4 systems.[101] This integrated air defense system was generally employed in accordance with Soviet doctrine. Thus, the Coalition employed NATO doctrine to disrupt and destroy the Iraqi IADS, which in turn had been developed based on experience against Soviet systems gained from operations over North Vietnam, recent Middle East conflicts, and the Libyan raid.

During the first night of the war, the Coalition orchestrated a complex array of attacks: Army helicopters destroyed key border radar sites, Tomahawk cruise missiles attacked command and control nodes, and F-4Gs carrying HARMs in conjunction with EF-111As and EA-6Bs jammed and destroyed SAM radar sites.[102] In contrast to US policy in North Vietnam where SAM sites around Hanoi were off limits to attack, the Coalition brought maximum firepower to bear against Iraqi command and control facilities and SAM sites around Baghdad to paralyze and destroy Iraq's ability to effectively respond against subsequent attacks.

The ultimate success of the offensive electronic combat campaign resulted in only 10 of the 38 Coalition aircraft lost during Desert Storm were damaged or destroyed by radar-guided SAMs.[103] While no suppression activity can realistically eliminate unguided AAA or IR SAMS, the presence of dedicated tactical radar jamming was still required in the later phases of Desert Storm even after the IADS had been broken down. As Major Hewitt quoted, "the Wild Weasels [F-4Gs] beat up on the enemy radar so bad that they essentially stopped radiating; and they'd come up for 4 or 5 seconds at a time and shoot and go back down," leaving the missile unguided and useless.[104] While the SAM itself would have gone ballistic and presented no threat to Coalition

aircraft, the radar sweeps would have provided accurate information for barrage AAA fire against attacking aircraft. Only the presence of dedicated tactical radar jammers such as the EF-111A and EA-6B can suppress radar systems that come up for a very short period of time to deny accurate targeting data to AAA gun batteries.

General Horner stressed in early February 1991 that American support for the war depended in large measure on the ability to operate "with less than anticipated" losses of human lives among Coalition airmen, soldiers, sailors, and Marines.[105] By the time Desert Storm ended, the Coalition's loss rate was about one fixed-wing aircraft per 1800 combat sorties.[106] This loss rate was 4.7 times lower than that experienced by the US over North Vietnam from January to December 1967 and some 14 times lower than that experienced during Linebacker II operations at the end of US involvement in December 1972.[107] The low loss rate stemmed from US electronic combat superiority and the decision to bomb from medium altitude after the first week. Electronic combat mitigated the threat posed by SAMs and radar-guided AAA, while medium altitude tactics mitigated the risk of infrared SAM systems and small caliber AAA. The achievement of significant reductions in losses came with a price tag however, since aircraft such as the F-16 and F/A-18 achieved less accuracy as a result of employing principally unguided munitions at medium altitude.

According to Thomas Keaney and Eliot Cohen the United States provided 96 percent of the Coalition's electronic warfare assets.[108] The US led SEAD campaign superbly orchestrated the employment of tactical radar jammers, drones, cruise missiles, stealth fighters, and deception, to gain surprise and enhance the mission effectiveness of ground attacks by Coalition strike packages. In fact, the unavailability of electronic warfare assets became a reason to abort a mission. Of the 100 attack packages flown from Incirlik AB, Turkey, only one was flown without such aircraft—the first night because these aircraft were not available due to political considerations by the Turkish government.[109]

EF-111As supported the very first wave of strikes against Iraq during Desert Storm and both the EF-111A and the EA-6B played crucial roles in denying radar-tracking data to SAMs and radar-guided AAA. Of the approximately 3,000 electronic warfare missions flown in Desert Storm, US air power conducted all but 80 of them.[110] As to the Ravens and Prowlers, eighteen EF-111As flew 1,105 combat missions from Taif Air Base, Saudi Arabia, twelve USMC EA-6Bs flew 504 combat missions, and twenty-seven USN EA-6Bs flew 1,126 combat missions.[111]

The support rendered by the EF-111A Raven and EA-6B Prowler was invaluable in saving highly trained and irreplaceable aircrew and valuable aircraft in Desert Storm just as their predecessors had in WW II, Korea, and Southeast Asia. Since the Gulf War, these two dedicated, tactical radar jamming platforms have continued their support of US objectives in Operations Southern Watch, Provide Comfort, and Deny Flight. In light of the increased sophistication and lethality of radar-guided threats and America's heavy reliance on non-stealth aircraft to project power, the need for a dedicated tactical radar jamming platform is greater than ever before.

Decision to Retire the EF-111A Raven

The EF-111A Raven airframe had a long and illustrious history. The Air Force selected the F-111A Aardvark as the airframe to become the newest dedicated radar jamming platform in the early 1970s. These all weather supersonic bombers were originally produced in 1966 and 1967 and a few had the distinction of flying combat missions in the Vietnam War. After considerable debate during the mid-1970s, the Air Force contracted to develop its own tactical radar jamming aircraft versus purchasing the Navy's EA-6B. The main concern at the time was the inability of the EA-6B to integrate itself within Air Force attack packages due to its slower speed.[112] The Raven went into service in 1981 with a total of 42 F-111As being modified into EF-111As.[113] The EF-111A is similar to the Prowler in that it uses the ALQ-99 Tactical Jamming System. The Raven carries 10 transmitters internally in a long canoe shaped fairing located underneath the front half of the airframe. The ability to carry ten transmitters internally reduced drag and accordingly added to the aircraft's range and loiter time. Furthermore, by carrying ten transmitters on every mission, the Raven was able to provide full frequency spectrum coverage in a three hundred and sixty-degree arc. Additionally, the Raven was operated by a two man crew, one pilot and one Electronic Warfare Officer (EWO). The Raven's ALQ-99E was much more automated than the one possessed by the Prowler allowing the single EWO to manage the increased workload. While not equipped with the AGM-88 Harm, the Raven was capable of speeds in excess if 1200 knots, which allowed it to be imbedded within any fighter or bomber attack package.[114]

On the other hand, the EA-6B Prowler is a twin engine, four seat, all weather electronic attack aircraft that is manned by one pilot and three Electronic Countermeasures Officers (ECMOs). The heart of the electronic system is the ALQ-99F Tactical Jamming System, which allows the ECMOs to analyze, record, target, and jam enemy ground and airborne radars.[115] Initially, the Prowler had been configured as a two seat aircraft and designated the EA-6A, however do to the complexities of the ALQ-99F, the EA-6A was modified into the current four seat

EA-6B. The EA-6B possesses four wing stations and one centerline station each capable of carrying one jamming pod, one high speed anti-radiation missile (AGM-88 HARM), or a fuel tank. The Prowler is a sub-sonic, non-afterburning jet aircraft with a top speed of 565 knots, but with a normal operation speed of 420 knots.[116] Additionally, the Prowler was upgraded with the USQ-113, which gives the aircraft the capability to jam tactical communications.[117]

Though the Raven and Prowler possessed unique capabilities, both airframes conducted similar missions. Three primary tactical jamming missions were performed: Stand-off Jamming, Close in Jamming, and Direct Support. Stand-off jamming is conducted over friendly territory and is used to screen the marshalling of forces or heavies such as AWACS, tankers, or reconnaissance aircraft. Close in jamming assisted friendly attack packages with penetrating through a defended border. Direct support missions require the escorting EF-111A or EA-6B to cross into hostile territory with the attack package and suppress radar threats along the strikers' ingress and egress routes as well as in the target area.

The greatest challenge to an attack package is the penetration of an integrated air defense system. An Integrated Air Defense System (IADS) is composed of multiple sites with a variety of sensor systems that all feed into a command and control network. The command and control network process information and data from the various sites in order to develop a clear picture of the aerial environment and enemy intentions. The command center for a region then optimizes assigned defensive systems such as aircraft, SAMs, and AAA, to target and destroy incoming air threats. The use of early warning and acquisition radars to pass targeting data to target tracking radar systems protects TTRs from early detection and destruction by SEAD assets by allowing them to acquire targeting data without emitting.

Raven and Prowler jamming operations are generally oriented against early warning (EW), ground-control intercept (GCI), and acquisition (ACQ) radars. The degradation of EW, GCI, and ACQ radars forces target tracking radars (TTRs) into autonomous operations in order to identify and track attacking aircraft. When the TTRs radiate, they are targeted for destruction through the

use of HARMs. Radar jamming and HARM operations need to be integrated to maximize combat effectiveness and contribute to mission success.

Operation Desert Storm demonstrated the outstanding effectiveness of joint operations in the performance of the suppression of enemy air defense mission. After Desert Storm, the EF-111A and EA-6B continued to provide its valuable force multiplier capability during subsequent "No Fly" operations as part of Operations Southern Watch and Provide Comfort. The Ravens flew from Incirlik AB, Turkey as well as Dhahran and Al Karj, Saudi Arabia, while the Prowlers performed their missions from carriers based in the Persian Gulf.

The shootdown of Captain Scott O'Grady's F-16 Fighting Falcon by a radar-guided surface-to-air missile during Operation Deny Flight highlights the need for a dedicated tactical radar jamming platform to support non-stealth aircraft. At the time of this incident, neither EF-111s nor EA-6Bs were on station to support Deny Flight operations.[118] While stealthy aircraft provide unique capabilities, there are significant limits on the ability to employ the currently slow moving, black colored aircraft during daytime conditions. Furthermore, the acquisition of stealth aircraft has been few in number due to cost considerations, thus the US will continue to rely heavily on predominately non-stealth aircraft. Additionally, since future operations will probably entail coalition partners, the US may need to maintain a tactical radar jamming system to enhance coalition air efforts.

However, fiscal constraints and a changing security environment have repeatedly resulted in reductions in force and the downsizing of the military equipment during the late 20th Century. The end of the Cold War, symbolized by the destruction of the Berlin Wall, victory in Desert Storm in March 1991, and the disappearance of a peer superpower threat, has resulted in the political forces of the United States shifting their focus from a global perspective to a more domestic perspective. This change in policy outlook resulted in a diminishing budget for the US military and the necessity to find and implement cost saving measures. Congress and the President went in search of the "Peace Dividend."

Due to dwindling budgetary resources in the mid 1990s the Air Force needed to find ways to cut expenses in order to support readiness and combat capabilities. This requirement was not only being felt by the Air Force but throughout the Department of Defense. The decision to emphasize joint operations and eliminate duplication of efforts was helped along by Congressional inputs to the Department of Defense. In a landmark Senate floor speech in July 1992, Senator Sam Nunn (D-GA) called for the end to what he termed unnecessary and wasteful duplication within the Department of Defense.[119] Senator Nunn suggested that missions performed by two or more services be consolidated into a single mission.[120] He specifically named electronic combat aircraft.[121]

One area suggested for consolidation was in the realm of airborne electronic warfare. Both the United States Air Force and the United States Navy possessed a tactical radar jamming platform based on the ALQ-99 Tactical Jamming System. The Air Force possessed the EF-111A Raven, while the Navy and Marine Corps operated the EA-6B Prowler. While both of these weapon systems possessed unique capabilities, some sources believed possession of these two airframes was redundant. After analyzing the issues, the Air Force made the decision to retire the EF-111A Raven. The Air Force, however, recognized the importance of electronic combat support and in close coordination with the Navy, recommended handing over the tactical radar jamming mission to the Navy's EA-6B Prowler.

In February 1993, however, Chairman of the Joint Chiefs of Staff General Colin Powell countered this position and specifically recommended retaining both aircraft, citing complementary not duplicative capabilities that significantly benefit the Department of Defense.[122] Not withstanding General Powell's recommendation, only two years prior, in May 1995, the congressionally mandated Commission on Roles and Missions of the Armed Forces revisited the issue of alleged redundancy in tactical electronic warfare aircraft.[123] The Commission suggested consolidation of several missions under a single platform or service. One recommendation called

for the retirement of the EF-111A and shifting the entire mission, with increased funding, to the EA-6B.[124]

However, the Pentagon pre-empted the Roles and Missions of the Armed Forces Commission's recommendation by decisions incorporated in Program Budget Decisions (PBD) 752 and 753 in December 1994.[125] PBD 752 increased funding and manning appropriations for the Prowler by $656 million beginning in fiscal year 1996, while PBD 753 cut funding for the Raven by $1.482 billion through the end of fiscal Year 1997.[126] Over $1 billion of the EF-111A savings were obtained by terminating the System Improvement Program that would have upgraded the Raven's ALQ-99E Tactical Jamming System. The shifting of funds and the decision by top Air Force officials to retire the EF-111A left little doubt that the EA-6B was intended to be the sole source of Joint Suppression of Enemy Air Defense support for the US military.

The debate on retiring or maintaining the EF-111A was very energetic and focused on five key areas.[127] One argument put forward for the continuance of the EA-6B was the fact that 127 EA-6Bs existed versus 40 EF-111As. The rational was that quantity was important if a single platform was to support the operational requirements of two services. Secondly, the cost to operate the Prowler was calculated to be $3,255 per flight hour versus $5,500 for the Raven. Third, both aircraft were in need of substantial upgrades to their software and hardware to be able to counter third and fourth generation anti-aircraft missile and AAA systems. To fund the upgrade of both aircraft, in a time of diminishing resources and no peer threat, was believed to be a poor return on the investment in light of newer emerging programs that needed funding. A fourth argument put forth was that the EA-6B possessed a small tactical communications jamming system called the USQ-113. This system gave the EA-6B a unique capability the EF-111A did not possess. Finally, some even proposed that having four aircrew members versus two would be a tactical advantage due to increased situational awareness.

On the other hand, the primary arguments against the Prowler's selection as the sole tactical jamming platform centered around performance capabilities between the two aircraft and

differences in employment doctrine and tactics between the USAF and USN.[128] As discussed before, the Prowler is not capable of supersonic flight, which is one of the principal tactics used in a high-threat environment by USAF attack aircraft. Furthermore, the Raven had slightly greater advantages in service ceiling, range, and endurance. Differences in the tactical employment of the two aircraft do exist; however, these differences have never resulted in the inability to provide effective radar jamming. These two areas were evaluated before the decision to retire the EF-111A Raven was made and were not considered "show stoppers."[129]

In the end, three key facts weighed in against the Raven. Historically, the F-111A was developed as a joint attack aircraft to replace the F-4 for the Navy and Air Force, but as the aircraft's size and weight increased it was no longer acceptable to the Navy because the aircraft could no longer operate from a carrier deck. Secondly, past decisions by the Air Force not to give HARM capability to the EF-111A due to the existence of the F-4G strictly limited the Raven's capability to radar jamming. Finally, the Air Force was promoting the idea that stealth aircraft required no outside electronic support to perform their mission, thus no reason existed to maintain the EF-111A. In the end, the EA-6B was the only viable choice, it could operate off carriers, the Navy wanted the mission, and the Navy possessed strictly non-stealth aircraft necessitating the continuation of carrier-based electronic support.

In response to the decision to retire the EF-111A, the Joint Requirements Oversight Council (JROC) recommended the creation of five joint-service EA-6B squadrons consisting of four aircraft each and that the EF-111A should be retired by the end of fiscal year 1997.[130] The five new Joint-Service Expeditionary Squadrons fall under the command of Navy and are manned by both Air Force and Navy aircrew. When these units deploy in support of a regional Commander in Chief (CINC), the Navy will be responsible for administrative support. This consolidation of a tactical mission was unique in military history in that service members from two separate services would train, fly, and fight together as a single unit and under the command of one service.

On March 25, 1996, the Final Memorandum of Agreement between the Joint Chiefs of Staff, US Navy, US Marine Corps, and US Air Force was issued.[131] The issues resolved by this MOA included: USAF crews are to be trained and qualified in the complete range of EA-6B operations to include carrier qualification; the Navy is responsible for ensuring all field grade officers are given equal consideration for commanding officer, executive officer, and department head billets; the Department of Navy is required to issue EA-6B tactics for the support of joint operations to the CINCs as soon as possible and the MOA directed the Air, Land, Sea Applications (ALSA) Center to develop a joint-service tactics, techniques, and procedures (TTP) manual followed by the updating then of the EA-6B Tactics Manual (TACMAN).

The retirement of the EF-111A was postponed until 30 Jun 98 as a result of the Navy's inability to reach an operational strength of 104 EA-6B aircraft by 1 Oct 97 in accordance with the March 25, 1996 Memorandum of Agreement.[132] After a solid record of performance that included support to Operations Eldorado Canyon, Just Cause, Desert Storm, and Deny Flight to name a few, the venerable Raven was finally retired on 30 Jun 98. The EF-111A fleet is now mothballed at Davis Monthan AFB, Tucson, Arizona.

The protection of Air Force, Army, and Navy aviation assets from detection by early warning and acquisition radars now rests solely with the EA-6B. The critical issues now concern how well the integration of the Prowler is progressing and can the Navy meet its requirements in terms of supporting multiple USAF operations simultaneously. Four questions need to be answered in order to predict whether or not the EA-6B will successfully function as an EA asset within USAF SA and AI attack missions. First, are the crew members of the EA-6B community being taught the skills necessary to successfully integrate their capabilities with USAF attack aircraft by the Replacement Air Group? Secondly, is the Prowler-USAF community being integrated by means of realistic training scenarios and exercises within the United States as well as overseas and do these exercises actually reflect real-world contingency capabilities? Thirdly, does the EA-6B possess the capability to support the omnidirectional threat picture found in a medium-

to-high threat IADS environment? Finally, have successful work arounds been created for EA-6B airframe limitations versus the USAF aircraft they would support?

Interviews and surveys with current Air Force and Navy officers involved in the new Joint Expeditionary Squadrons provided a wealth of information concerning ongoing efforts to eliminate academic deficiencies, provide realistic joint training, resolve mobility shortfalls, and fix equipment incompatibilities and limitations. The continued success of these efforts is critical to the future viability of the Navy's capability to effectively support multiple Air Force contingency operations in different theaters simultaneously.

Prowler Fulfillment of USAF Requirements

The successful integration of the EA-6B Prowler into Air Force operations is of the highest importance in view of the USAF's retirement of the EF-111A Raven and the passing of the tactical radar jamming mission to the US Navy. In light of this decision, the USAF has agreed to provide a constant pool of Electronic Warfare Officers and pilots to the Navy to facilitate successful joint operations and USN support to USAF operations.[133] This section evaluates the joint effort and attempts to determine whether or not the Prowler will be able to successfully support USAF strategic attack (SA) and air interdiction (AI) missions in a medium-to-high threat integrated air defense system (IADS) environment.

In order for Prowler integration to be effective, four questions need to be answered in the affirmative to predict whether or not the EA-6B will successfully support USAF SA and AI attack missions. First, are the crew members of the EA-6B community being taught the skills necessary to successfully integrate their capabilities with USAF attack aircraft by the Replacement Air Group? Secondly, is the Prowler-USAF community being integrated by means of realistic training scenarios and exercises within the United States as well as overseas and do these exercises actually reflect real-world contingency capabilities? Thirdly, does the EA-6B possess the capability to support the omnidirectional threat picture found in a medium-to-high threat IADS environment? Finally, have successful work arounds been created for EA-6B airframe limitations versus the USAF aircraft they would support? The answers to these four questions will determine the answer to the monograph question: Can the US Navy's EA-6B Prowler successfully provide Electronic Attack support to US Air Force strategic attack and air interdiction missions in a medium-to-high threat integrated air defense environment?

To answer the question whether or not EA-6B aircrew are acquiring the initial skills and experience necessary to successfully integrate with USAF attack aircraft, three levels of analysis are necessary: first, does the Replacement Air Group academic syllabus emphasize the instruction

of joint doctrine as a common language between the services; secondly, have EF-111A lessons learned over the past seven years been officially incorporated into top-off training programs; and, thirdly, are new ECMOs and pilots receiving realistic tactical flight training. The training conducted by the Replacement Air Group is important because this organization is responsible for training all flight officers transitioning to the EA-6B Prowler at Whidbey Island. Therefore the core training and education provided by this organization significantly impacts the combat capability of future aviators.

According to survey results, the teaching of joint doctrine has not been incorporated into the RAG training curriculum. The curriculum is currently focused on instructing basic aircraft systems knowledge such as fuel, electrical, and engines, not tactics or overseas scenarios. Furthermore, the training syllabus does not possess a "top off" program prior to graduation nor does it possess a block of instruction on lessons learned from EF-111A deployments with Coalition partners. A "top off" program is critical because it emphasizes tactical employment of the aircraft and its systems in real-world scenarios and forces students to find work arounds to various threat arrays and equipment failures in order to successfully accomplish the mission. The issue of EF-111A lessons learned is not a parochial concern. Navy air operations at sea are generally conducted independently of international participants on a day-to-day basis, whereas being land-based in support of contingency operations such as Southern and Northern Watch require close integration with Coalition partners on a day-to-day basis. Therefore, the failure to provide tactical training and pass along lessons learned from seven years of contingency operations experience is resulting in a tremendous loss of contingency operations experience. A factor contributing to the failure to integrate Air Force lessons learned into the RAG curriculum is the omission of Air Force officers as instructors in the RAG. The assignment of Air Force instructors would facilitate the exchange of joint doctrine and lessons learned.

Surveys returned by EA-6B Air Force aircrew also reflected the failure to include tactical training and lessons learned after joining their Joint Expeditionary Squadrons. Thus, new aviators

are failing to receive key academic training in either the RAG or their operational squadron. While the academic deficiencies of the RAG and Joint Expeditionary Squadrons are easily corrected, tactical flight training problems will require greater efforts to correct. Three predominant reasons were given for the deficiency in flight training: budgetary constraints limiting flight hours, restrictive flight safety rules to minimize the chance of aircraft mishaps, and a lack of initiative on the part of Navy leadership to incorporate Air Force tactics, techniques, or procedures, into the Navy way of doing business. The combination of budgetary constraints and restrictive flight rules create an environment where limited training sorties and restricted tactical operations significantly dimish aircrew proficiency over time. Currently, after a squadron returns from its deployment its budget is reduced, the crews stood down, and the aircraft slowly regenerated over time. Generally, only one aircraft is available for the first month and over the following months the remaining aircraft become fully mission capable (FMC). According to the Air Force Detachment Commander at Whidbey Island NAS, the primary reason it takes months to get the Prowlers back up to FMC is the scarcity of spare parts due to funding reductions upon completion of a deployment and the lack of spare parts. Critical spare parts first go to deployed units, then to units working up for deployments, and whatever is left over goes to the units returning from deployments. Thus, while the crews and aircraft return stateside in a fairly high degree of readiness, their skills and readiness deteriorate fairly rapidly in the months following their return. Therefore if a crisis erupts, stateside crews may have received only minimal proficiency training, aircraft may not be FMC, and the scarcity of spare parts may hinder the generation of additional aircraft to support the contingency. If currently deployed units are pulled from one operation to support a new contingency, then the losing commander is obviously stripped of his electronic warfare assets and the lives of his remaining aircrew members will be placed at risk.

The Navy is attempting to remedy its training deficiencies through the Electronic Attack Weapons School (EAWS). The EAWS became operational in 1996 and has established a four-level tactics curriculum designed to systematically advance the training proficiency of Prowler

crews. Furthermore, Air Force officers have provided the EAWS with lessons learned from various contingencies to be incorporated into the tactics curriculum. Recently, the EAWS established a standard checkride to ensure uniformity in knowledge and performance and to validate training programs for all Prowler crews. Pragmatic business decisions based on fiscal constraints continue to result in the low prioritization of returning Prowler aircraft and crews, resulting in diminished aircrew proficiency do to the lack of fully mission capable aircraft.

While the Navy is attempting to fix training deficiencies through the EAWS, this action will not sufficiently resolve training deficiencies or mobility readiness issues unless the Navy reprioritizes funding requirements. The aircraft maintenance aspect of the training problem can only be rectified by the Navy's recognition of the critical role the Prowler plays in contingency operation plans and then funding the system appropriately to support its world-wide contingency mission. Although the Joint Expeditionary Squadrons have been designated to support Air Force contingency operations, they continue to be treated in the same way as the Fleet Squadrons. The requirement for immediate employment to support crisis contingency plans demands a high level of constant readiness, which is not compatible with past Naval readiness and maintenance cycles. In the past, the Navy operated its squadrons on an 18-24 month cycle to support preplanned carrier deployments. The Air Force's requirement for an immediate response capability requires the Navy to change its past carrier battle group maintenance cycle to support current and future operations. This requires the Navy to acknowledge the differences in mission between Fleet and Joint Squadrons and to accordingly fund the Joint Expeditionary Squadrons.

The second issue to be addressed evaluates the effectiveness of the joint Prowler community by assessing the quality of training exercises being conducted. Realistic training scenarios and exercises stateside as well as overseas provide the optimum training environment and provide the opportunity for the services to evaluate the true effectiveness of the Joint Expeditionary Squadron concept. Two areas need to be looked at to evaluate the effectiveness of aircrew training: the quality of the scenario being used and the actual training conducted by the aircrews involved.

The use of current real-world scenarios present the optimum training environment by providing a realistic threat environment that may have applicability in the future. An effective training scenario, however, is only as good as the training conducted by the participating aircrews. The ability to fly doctrinal mission profiles, perform threat reactions, and educate airmen from other platforms are three keys to effective composite force training.

The Prowler community is participating in some of the best training opportunities around the world. The Prowlers have participated in the United States Air Force's Green Flag and Red Flag exercises, Canada's Maple Flag, and South Korea's Cope Thunder. Locally, the Prowlers regularly conduct Large Force Exercises with the 366th Fighter Wing at Mountain Home AFB, Idaho as well as with F-15s and F-16s of the Oregon Air National Guard. Additionally, the Prowlers are currently supporting Coalition aircraft in support of Operations Northern Watch and Southern Watch over Iraq. These exercises definitely provide real-world scenarios and a realistic environment. Additionally, participation in these exercises and operations allow Prowler aircrews to highlight their capabilities and to develop standard operating procedures to integrate their supporting role into Air Force packages.

The ability to actually employ the Prowler to its full capabilities, however, has been limited. As a consequence of the February 3, 1998 incident, in which a US Marine Corps EA-6B appeared to violate an Italian altitude restriction and cut a gondola cable resulting in the death of all occupants, USN Prowlers were restricted to operations above 5,000 feet above the ground (AGL).[134] This restriction has recently been lowered to 1,500 feet AGL. This altitude restriction reduces aircrew proficiency in the low altitude environment which is key in supporting low level ingress by attacking aircraft as in El Dorado Canyon and Desert Storm and defensive threat reactions. Furthermore, on a day-to-day basis, hard maneuvering has been limited during threat reactions and other high performance turns to three or four "Gs", aircraft dependent, to preserve the life expectancy of the Prowler do to its advancing age. Finally, threat reactions and tactics generally call for the employment of two aircraft to support USAF operations in order to provide a

degree of mutual security and wide-area electronic coverage. In order to function effectively as a two-ship, training must be regularly conducted as a two-ship. Regretfully, budgetary shortfalls and scarcity of spare parts result in infrequent two-ship training operations at home station, while overseas flight operations are limited to the medium altitude block while flying in support of Southern Watch and Northern Watch due to risk management.

Overall, the Prowlers are attending some of the finest exercises in the world and supporting real-world contingency operations, however the quality of training is not equally commensurate. The inability to practice low-altitude tactics in the low altitude environment, conduct multi-ship operations regularly, and perform realistic threat reactions, all contribute to increased risk to crews and mission success.

The third issue of concern addresses the EA-6B Prowler's capability to jam the omnidirectional radar coverage found in the medium-to-high threat integrated air defense environment. The Prowler possesses numerous capabilities in this area through the integration of the ALQ-99F, USQ-113, and HARM.[135] Two areas need to be evaluated to determine the Prowler's success in this type of environment: whether or not the aircraft can carry enough transmitters, and secondly, can it survive while in the escort role. The EA-6B possesses four wing stations and one centerline station each capable of carrying one jamming pod, one high speed anti-radiation missile (AGM-88 HARM), or a fuel tank. Therefore, the Prowler is capable of carrying up to ten transmitters externally, just as the EF-111A did internally, to counter radar threats. Depending on the threat array multiple EA-6Bs may be required if drop tanks are required do to the range or loiter time needed to successfully accomplish the mission. Furthermore, if the Prowler is required to maximize its jamming capacity at the expense of carrying a HARM, then integration with F-16 HTS and F/A-18 HARM carrying aircraft becomes a critical planning consideration.

Integration with F-16 HTS and F/A-18 aircraft provides an additional work around to the survivability issue of the slower moving EA-6B. The Prowler is a sub-sonic, non-afterburning jet aircraft with a normal operational speed of 420-450 knots. Typically, Air Force attack aircraft

penetrate enemy airspace in excess of 480 knots, therefore Prowlers typically need to lead the package to ensure proper jamming alignment and thus may require dedicated escort for protection if enemy fighters may be present. Moreover, the ALQ-99F provides the Prowler with a superb built in radar warning receiver, enhancing its ability to detect radar-guided threats. This capability not only allows the Prowler to maneuver to avoid radar threats but to pass threat calls to the strike package so they can maneuver to avoid becoming engaged. This electronic capability significantly enhances the survivability of limited aircrews and the success of the mission.

The final issue was to determine whether or not successful work arounds have been found for four issues: performance limitations, connectivity restrictions, insufficient dedicated assets, and development of independent mobility packages. The first of these, is the slow speed of the Prowler relative to Air Force aircraft and was one of the key decision criteria that the Air Force used to reject acquisition of the EA-6B.[136] Secondly, connectivity between the EA-6B and national airborne electronic intelligence assets and USAF strike aircraft such as the F-15E and F-16 was recognized by the General Officer Steering Group headed by Rear Admiral Francis W. Lacroix in report dated June 21, 1995.[137] These two issues remained key concerns during the Raven versus Prowler debate by Air Force leadership in the early 1990s. The remaining two concerns arose after the Air Force and Navy established the first Joint Expeditionary Squadron: the Navy's decision to cancel one Joint Expeditionary Squadrons in favor of adding a new Fleet Squadron; and, the Navy's reluctance to establish four independent mobility packages to support each of the remaining Joint Expeditionary Squadrons.

Tactics and techniques have been developed to successfully place the Prowler in the correct alignment to support strike packages to compensate for the Prowler's slower performance characteristics. Prowler units supporting Air Force operations over Iraq have successfully implemented these work arounds. Mission planning on the other hand requires careful effort on the part of mission planners. The Air Force's universal Air Force Mission Support System (AFMSS) is not compatible with the Navy's Tactical EA-6B Mission Planning System (TEAMS).[138] The

AFMSS is a modular system designed to support the mission planning requirements of most Air Force aircraft and does not currently have the capability to interface with TEAMS. Therefore, if a Prowler squadron is chopped to support USAF operations, a separate TEAMS package will have to be deployed. A further system incompatibility affecting integration is aerial refueling. USAF fixed-wing aircraft are equipped for boom refueling operations; the EA-6B requires a drogue. This means the Prowler can receive fuel from the KC-10A that possesses both a boom and drogue. However, the KC-10A has a significant airlift capability in addition to its refueling capability that places it in very high demand during any military operation requiring airlift. Alternatively, the KC-135 is a single point refueler, which then requires a second aircraft to refuel mix capability packages. Thus, the introduction of EA-6Bs into Air Force operations requires judicious employment of tanker assets.

The connectivity issue surrounds two key aspects: Have Quick radios and the Integrated Data Modem (IDM).[139] Almost all Air Force aircraft are equipped with the Have Quick radio to minimize the effects of jamming and to make the interception of transmissions more difficult. The Navy is behind the Air Force in equipping its aircraft with this radio system, but is planning to equip all of its Prowlers in the future. Currently the EA-6Bs deployed in support of overseas Air Force operations are equipped with Have Quick. However, if a contingency operation occurs that requires non-Have Quick equipped Prowlers to be used, significant connectivity concerns will arise if communications jamming is present. The IDM allows the transmission of data between aircraft such as the RC-135 Rivet Joint, E-3B AWACS, F-15C, and F-16 HTS to enhance situational awareness while simultaneously cutting down on voice transmissions. The Navy is once again working to acquire a compatible system for its aircraft so that air operations can be more closely integrated. The enhanced situational awareness that will occur once both services are linked will decrease the potential for fratricide, increase threat avoidance capabilities for strike packages, and enhance the ability to target enemy weapon systems beyond visual range. While these connectivity issues are important and have yet to be fully resolved, operations are being conducted

satisfactorily. These issues were present during Desert Storm and did not significantly impact the air campaign.

The MOA called for the establishment of five Joint Expeditionary Squadrons, in actuality the Navy stood up only four Joint Expeditionary Squadrons. The fifth squadron was diverted and turned into a Fleet Squadron, which means it is primarily tasked with supporting carrier battle group operations not Air Force contingency operations. This is a significant decrease in the capability required by the MOA and of assets available to support Air Force missions. The Navy committed to the Air Force at the time the decision was made to retire the EF-111A to fund the expansion and modification of its EA-6B fleet to provide five squadrons to support Air Force contingency operations. This significant reduction in capability is bound to influence the ability of the Navy to support multiple Air Force contingency operations in multiple theaters.

Furthermore, the Air Force Detachment Commander stated the Navy has not developed prepackaged mobility contingency pallets, to include spare parts and maintenance capabilities, to support short-notice operations due to fiscal constraints and the lack of mobility experience. The Air Force is attempting to resolve the mobility training issue by training Naval personnel on current practices. Mobility training, however, will not suffice for the Navy's inadequate funding of spare parts and maintenance requirements to support Air Force requirements or its commitment under the MOA. In the past, the Naval aircraft maintenance system was based upon being part of a carrier battle group and of consolidating third and fourth level echelon maintenance within the air wing. Land-based operations at Air Force bare base facilities require the Navy to adopt and resource a new organizational structure capable of operating independently of the carrier. Furthermore, the Navy needs four independent maintenance and mobility organizations to support each Joint Expeditionary Squadron. To properly support Air Force mission requirements, the Navy still needs to resolve issues concerning the acquisition of spare parts and the development of an independent maintenance capability for land-based operations. Therefore, the current ability of

the Navy to employ Joint Expeditionary Squadrons in support of the Air Force contingency operations is limited at two levels—the number of aircraft available as well as the ability to deploy and sustain them on short-notice.

Conclusion

History has repeatedly demonstrated man's ability to develop countermeasures to new weapon systems. The birth of radar reflected this trend in that radar was developed to counter a growing air threat. The British developed the first integrated air defense system during the 1930's by networking radar sites along their eastern coastline to provide early warning of air attacks from the continent of Europe with Fighter Command.[140] The significant contribution radar made to the successful defense of Britain in 1940 resulted in the recognition that the means to defeat this system also needed to be found if a successful strategic bombing campaign was to be conducted. Thus, World War II witnessed the development of the modern theory of Electronic Warfare and dedicated tactical radar jammers.

Today, the proliferation of modern surface-to-air missile systems, early warning and acquisition radars, and anti-aircraft artillery weapon systems require a robust EA capability. Even though the stealthy B-2 and F-117 garner a great deal of attention, these aircraft represent a small percentage of the United States aerial arsenal. Thus, the United States will continue to need an EA platform that to provide tactical jamming support to non-stealthy aircraft in a medium-to-high threat environment in a joint or combined environment.

The debate on retiring or maintaining the EF-111A was very energetic and focused on five key areas: the existence of 127 EA-6Bs versus 40 EF-111As, costs of $3,255 versus $5,500 per hour for the EA-6B and EF-111A respectively, the inability to fund upgrades for both aircraft do to fiscal constraints, the possession of the USQ-113 tactical communications jamming system by the EA-6B, and the proposal that the EA-6B's larger crew enhanced situational awareness.[141] While all of these elements are true and General Powell clearly articulated that the EF-111A and EA-6B provided complimentary support not duplicative, the final decision to retire the EF-111A was a pragmatic business decision based on fiscal limitations.

With the retirement of the EF-111A Raven, the EA-6B is the only platform capable of jamming tactical radar threats. The ability to successfully integrate this limited asset into joint and combined operations has significant impacts on the survival of aircrews and aircraft as history has repeatedly proven in the age of radar directed threats. This monograph explored this joint effort and attempted to determine whether or not the Prowler can successfully support USAF Strategic Attack and Air Interdiction missions against a modern medium-to-high threat integrated air defense system (IADS).

Four questions were addressed in order to determine how well the EA-6B would function as an EA asset within USAF SA and AI attack missions. First, are the crew members of the EA-6B community being taught the skills and given the experiences necessary to successfully integrate their capabilities with USAF attack aircraft? Secondly, does the EA-6B possess the capability to support the omnidirectional threat picture found in a medium-to-high threat IADS environment? Thirdly, is the Prowler-USAF community being integrated by means of realistic training scenarios and exercises within the United States as well as overseas and do these exercises actually reflect real-world contingency capabilities? Finally, have successful work arounds been created for EA-6B airframe limitations versus the USAF aircraft they would support?

The answers to all four questions indicate that the Prowler can provide critical jamming support to USAF attack missions if given sufficient lead time to generate aircraft, acquire spare parts, and build mobility packages; and, dedicated KC-10A or KC-135 tanker assets are available to support Prowler refueling requirements. The EA-6B is currently being upgraded with Have Quick radios and IDM in order to enhance connectivity and interoperability with Air Force aircraft. Furthermore, the ALQ-99F is being upgraded through the Improved Capabilities III program with new receivers and exciters to increase the jamming capability of the Prowler and enhance system reliability to meet future radar threats.

To be fair, the Joint Expeditionary Squadrons concept as well as the integration of Air Force aircrews have only just begun. All new programs have growing pains and this one is no

different. The Navy is in the process of making a significant break with the way Naval flight operations have been conducted in the past. Three recommendations can be made based on the research findings of this monograph.

First, when the Joint Expeditionary Squadrons or Fleet Squadrons deploy in support of Air Force assets, the squadron will no longer have the carrier to provide for its needs. The Prowler squadron will need to be self-sufficient and capable of moving anywhere in the world on short-notice, conduct its mission, and sustain its operations. Thus, the Navy will have to fund the building of mobility pallets and acquisition of spare parts, conduct mobility training, and enhance its interoperability with the Air Force as well as future Coalition partners. To address these current shortfalls, the Navy may want to look towards the Marine Corps, who typically deploys Prowler squadrons independently of task organized aviation combat elements.

Secondly, the lack of Air Force instructors in the Replacement Air Group (RAG) and Electronic Attack Weapons School (EAWS) needs to be addressed. The presence of Air Force officers in these organizations would facilitate the exchange of information between the services and the ability to meet future Air Force contingency requirements.

Finally, if the Navy is going to honor its commitments to regional CINCs and the USAF to provide Prowler support for contingency operations, the Navy needs to raise the maintenance, funding, and training priority of returning Prowler squadrons. Under the current system, the Navy would be unable to adequately support USAF and CINC requirements in one or more short-notice contingencies operations, and continue to support preplanned deployments, without stripping assets from another CINC or operation. To ensure the readiness of Prowler aircraft and the combat skills of aircrew, the Joint Expeditionary Squadrons should be organized as an independent command and funded appropriately to allow the squadrons to be simultaneously deployed to four separate theaters. Only by creating an independent command will the Joint Expeditionary Squadrons be employed and supported in a manner commensurate with their mandate to support Air Force operations. As long as the Expeditionary Squadrons continue to be part of the traditional Fleet

Squadron organization, they will not receive the resourcing necessary to perform their primary mission.

The ability of the Navy to support United States contingency operations is of paramount importance in light of the fact that the United States provided 96 percent of the Coalition's electronic warfare assets during Desert Storm.[142] The retirement of the EF-111A requires the Navy to be able to respond anywhere in the world, on short notice, to support Air Force and possibly Coalition operations. If the Navy becomes unable to meet contingency requirements in peacetime without planning to strip assets from preplanned operations, then the Navy's ability to support actual wartime requirements would become highly questionable.

The US military's ability to dominate the electromagnetic spectrum through the effective synchronization of electronic warfare assets is central to the success or failure of our military operations.[143] The radar threat of the 1990's and our heavy reliance on conventional, non-stealthy aircraft require the United States to maintain a strong tactical radar jamming capability. In light of fiscal constraints and past Department of Defense decisions, the effective employment of Electronic Warfare is now clearly a joint mission.

Keep in mind what General Curtis LeMay said on June 15, 1984:

> "To commit the youth of our nation to lay their lives on the line, we must at least take the viewpoint to equip them with the best weapons that time and technology can provide, and provide them with military leaders who are trained and encouraged to pursue the most innovative approaches to operations and tactics. With these elements in place, the remaining task is to train, train, train, under the most realistic conditions that can be imposed for the military operations that appear most likely."[144]

The creation of the Joint Expeditionary Squadrons is but the first step in an innovative approach to joint dependency. Cooperative training, interoperability, and connectivity will be the keys to successful joint operations in the future. Limited assets and the years it takes to develop an experienced aircrew member requires that the system works right the first time—there may not be the time or resources to relearn past lessons.

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